

SUMMARY OF RESEARCH

Validation of Centrifugation as a Countermeasure for Otolith Deconditioning During Spaceflight

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**Flight Experiment
Grant #: NCC 9-128
Experiment ID: 99-E039
Ops Name: SPIN
Period of Performance: 6/14/2001 – 9/30/2004**

Principal Investigator,

A handwritten signature in black ink, appearing to read 'Steven T Moore', is written over a horizontal line.

**Steven T Moore PhD
December 3, 2004**

Experiment Summary (extract from Experiment Document)

In contrast to previous studies, post-flight measures of both otolith-ocular function and orthostatic tolerance were unimpaired in four payload crewmembers exposed to artificial gravity generated by in-flight centrifugation (Fig. 1B) during the Neurolab (STS-90) mission. The aim of the current proposal is to obtain control measures of otolith and orthostatic function following short duration missions, utilizing the centrifugation and autonomic testing techniques developed for the Neurolab mission, from astronauts who have not been exposed to in-flight centrifugation. This will enable a direct comparison with data obtained from the Neurolab crew. Deficits in otolith-ocular reflexes would support the hypothesis that intermittent exposure to in-flight centripetal acceleration is a countermeasure for otolith deconditioning. Furthermore, a correlation between post-flight otolith deconditioning and orthostatic intolerance would establish an otolithic basis for this condition.

Summary of Research Activity

Activity for the first two years of the grant period were focused on preparation of the equipment and protocols for implementation of the experiment pre- and post-flight on subjects aboard short duration shuttle flights. The tragic loss of the Orbiter Columbia in February 2003 effectively ended the prospects of this project being implemented. Nevertheless, crew briefings were continued in May 2003 and a subject from STS-118 was recruited and pre-flight data was obtained in December 2003. Shortly thereafter NASA HQ officially deselected this proposal. The European Space Agency (ESA), which had financed refurbishment of the Neurolab flight centrifuge to be installed at JSC for use in this experiment, decided to continue implementation of this project at Star City in Russia (unofficially termed 'SPINSKI'). A European co-investigator on the current NASA proposal, Gilles Clement, is now the Principal Investigator for this new project, with Steven Moore a co-investigator. The final year of the project was spent finalizing the head-eye tracking system developed for use in this project and supporting the ESA implementation of the experiment. In addition, several publications were generated during the life of the grant related to the ground-based research carried out in support of the flight implementation.

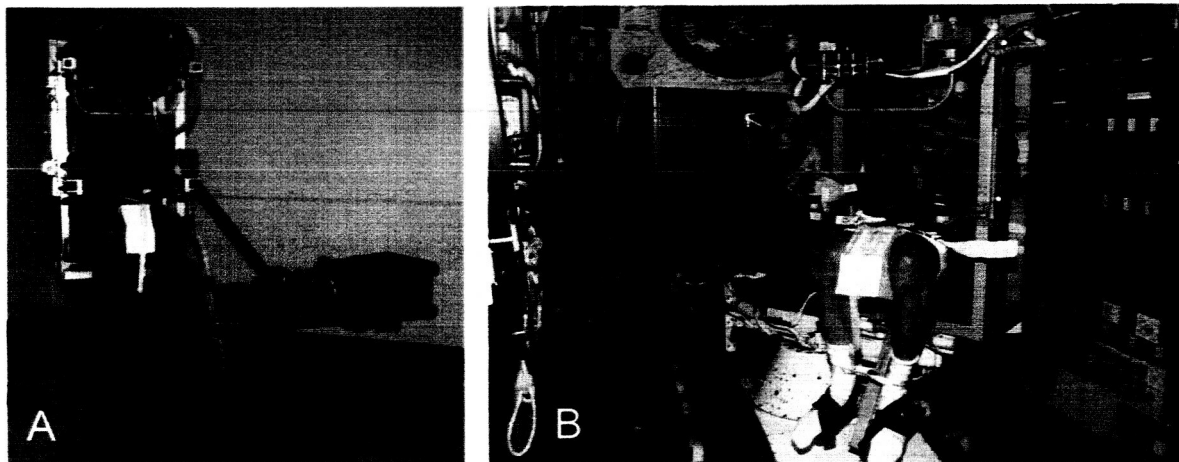


Fig. 1. The centrifuges used for this project. A The ground centrifuge, shown here during pre-flight Baseline Data Collection at JSC on the Neurolab mission, and B the flight model, which was refurbished by ESA for this experiment.

6/2001 – 6/2002

The first 6 months of activity concentrated on defining the experimental protocols (Experiment Document) and obtaining CPHS (Committee for the Protection of Human Subjects) approval. On 8/21/2001 the Critical Design Review was held at JSC, and revisions to the testing schedule were implemented in response to the feedback received at the CDR. For the remainder of this period the development of the experimental hardware was the primary goal. Two centrifuges were to be used for this project (Fig. 1): the ground centrifuge from the Neurolab (STS-90) mission (currently located at Mount Sinai in New York) was to be installed at KSC, and the flight model (refurbished by ESA at Aerospatiale in Bordeaux) to be installed at JSC. The major aim of the centrifugation portion of the experiments was to obtain three-dimensional eye position measurement during rotation to assess vestibulo-ocular reflexes. The eye tracker employed on the Neurolab flight was developed by ESA in 1996 using custom built hardware, and was loaned by ESA to the PI for the current project. Considerable technical problems were encountered in the use of this hardware, which required the PI's team to design a new system of head and eye movement recording.

The second aim of the experiment involved the measurement of fluid shifts during the operational tilt test (Fig. 2), performed on all rookie astronauts after landing to test for orthostatic intolerance (dizziness or inability to stand). Fluid shifts were to be determined using a Body Impedance Device (BIM) developed for the Neurolab mission. However, there was some concern over whether the BIM would interfere with the Med Ops testing, and on 4/3/2002 the BIM was tested during a standard Med Ops tilt test at JSC (Fig. 2B). The use of the BIM was found to have no adverse effects on Med Ops test results.

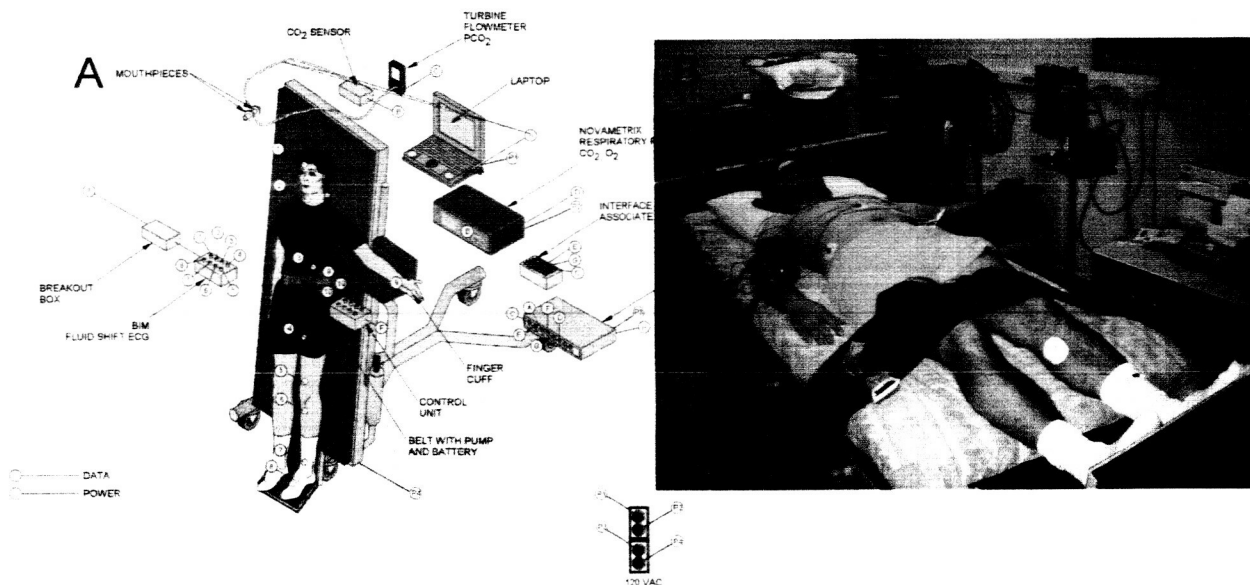


Fig. 2. Measurement of fluid shifts during the operational tilt test. A Schematic of the op tilt test, which is carried out routinely on all rookie astronauts on R+0. B An op tilt test was carried out at JSC by Med Ops staff, which included the impedance (BIM) device to be used in this study to monitor fluid shifts. The BIM was found not to influence the results of the Med Ops portion of the test.

6/2002 – 6/2003

Early in this period the final protocols were defined and the flight documents completed. A crew briefing (STS-117) was held on 12/13/2003. After the Columbia mishap a second crew briefing was held (STS-118 crewmember) on 5/12/2003, and the first subject was recruited. In addition, tests were conducted at Mount Sinai using the Neurolab ground centrifuge and a new head-eye tracker developed by the investigators, and these results were presented at the International Society for Posture and Gait (ISPG) conference in March, 2003.

6/2003 – 9/2004

Pre-flight data was collected from an STS-118 crewmember on 12/5/2003 on the ground centrifuge at Mount Sinai (Fig. 3), using the new head-eye tracking system developed by the investigators. On 12/13/2003 the project was deselected by NASA HQ. Shortly thereafter ESA indicated that the project would continue under a European PI (Gilles Clement). The remainder of the grant period was spent on further development of the head-eye tracker, which is currently utilized on another NASA grant (NNJ04HF51G: S. Moore PI), and is to be used on Cosmonaut subjects returning from the ISS in Star City in the ESA implementation of this project (SPINSKI – first subject tentatively scheduled for April 2005).



Fig. 3. Pre-flight data was obtained from a subject scheduled for STS-118 in December 2003. A Subject seated in the ground centrifuge at Mount Sinai, wearing lightweight swimming goggles with digital video cameras for acquisition of binocular eye movements. This system was developed by the investigators. B During testing, the subject viewed a laptop screen which displayed a pattern of moving vertical bars (optokinetic stimulus).

PUBLICATIONS

Peer-reviewed Journal

Moore ST, Clement G, Dai M, Raphan T, Solomon D, Cohen B (2003) Ocular and perceptual responses to linear acceleration in microgravity: Alterations in otolith function on the COSMOS and Neurolab flights. *J. Vest. Res.* 13: 377-393.

Moore ST, MacDougall H, Clark JB, Wuyts F, Lesceu X, Speyer JJ, Cohen B (2004) Spatial disorientation - how the brain interprets linear acceleration during flight. *J Vest Res* 14: 114.

Zhu D, Moore ST, Raphan T (2004) Robust and real-time torsional eye position calculation using a template matching technique. *Comp Prog Meth Biomed* 74: 201-209.

Moore ST, Cohen B, Raphan T, Berthoz A, Clement G (2005) Spatial orientation of optokinetic nystagmus and ocular pursuit during orbital space flight. *Exp Brain Res* 160: 38-59.

Moore ST, Diedrich A, Biaggioni I, Kaufmann H, Raphan T, Cohen B (2005) Artificial gravity: a possible countermeasure for post-flight orthostatic intolerance. *Acta Astronaut*: In Press.

Moore ST, Hirasaki E, Cohen B, Raphan T (2005) Instantaneous rotation axes during active head movements. *J Vest Res* In Press.

Conference Proceedings

Moore ST, Clement G, Raphan T, Berthoz A, Cohen B (2002) Spatial orientation of OKN on Earth and in microgravity. *Proceedings Barany Society Conference, Seattle, WA, September, 2003.*

Moore ST, Imai T, Schneiderman J, Raphan T, Cohen B (2002) Orienting linear vestibulo-ocular and vestibulo-collic reflexes during turning and centrifugation. *Proceedings Barany Society Conference, Seattle, WA, September, 2002.*

Moore ST, Imai T, Raphan T, Cohen B (2003) Head and eye movements during turning and centrifugation *Proceedings International Society of Posture and Gait (ISPG) Conference, Sydney, Australia, March 2003.*

Moore ST, Clement G, Raphan T, Cohen B (2003) Perceptual and Oculomotor Responses to Artificial Gravity: Results from the Neurolab STS-90 Centrifugation Experiments. *Proceedings, Humans in Space Symposium, Banff, Canada, May 2003.*

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MacDougall H, Moore ST, Cohen B (2004) Ambulatory monitoring of high frequency otolith stimulation. *Proceedings, Society for Neuroscience Annual Meeting, San Diego, CA, October 2004.*